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A comparative study of q angle and muscle activation during vertical jump among sportspersons

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Abstract
The quadriceps angle (Q angle), is formed between the quadriceps muscles and the patella tendon, is an important factor in the biomechanical performance or the knee joint. It is also considered a crucial factor for the proper posture and movement of the knee patella. Similarly, gastrocnemius and Tibialis anterior muscles play an important role in propelling the body upwards during vertical jump. This study had been conducted to measure the normal Q angle values among various male and female sportspersons and analyse the correlation between Q angle values and the muscle activation of Gastrocnemius and Tibialis Anterior during vertical jump. This Study was conducted on 15 males and 15 females of varied sport. It was found that Q angle was greater in young women than young men. The muscle activation of gastrocnemius and Tibilais anterior muscles was done using Delsys Trigno Avanti SeMG sensors and the data analysed using software Labchart 8 from AD Instruments, USA. A significant difference was found between the activation of males and females as well as correlation between Q angle and muscle activation.

Keywords: Surface EMG, gastrocnemius, tibialis anterior, Q angle

Introduction
The Q angle or the Quadriceps angle is the angle between which is also known as quadriceps angle, is defined as the angle formed between the patella and the hipbone. Biomechanically the functions of the lower extremity is affected by the Q angle. It also gives an idea about how the patella articulates in the knee joint and affects the quadriceps function in the knee [1, 2].

The Q angle of the human body is determined by the femur and the tibia and mediates the relationship between the hip and foot. The middle of the patella represents the axis of the angle [3]. The Q angle is measured by placing the axis of the goniometer at the centre of the patella. One arm of the goniometer is aligned with the anterior superior iliac spine and the other is lined up with the centre of the tibial tuberosity [4]. It is important for a well-functioning knee joint and for mobility such as running or walking. Q angle provides information about the alignment of the knee joint. Normal Q angle of men is 14 degree and women is 17 degree [5].

Studies have shown that a Q angle in excess of 15-20º can cause injuries in the patellofemoral joint [6]. Studies also indicate that women have a significantly greater Q angle than men. While the difference for this is not clearly documented, it can be assumed that this could be due to the structure of women's hips which are wide and designed to bear and give birth to a child [7]. Another reason for a greater Q angle is assumed to be a shorter femur in females which would cause a smaller Q angle [8].

Electromyography (EMG) is the procedure to find the electric signal of the muscle and is also a reliable method available for imaging muscle function and efficiency. In biomechanics, surface EMG signals are mainly used (i) to indicate the initiation of muscle activation (ii) to find its relationship to the force produced by a muscle (iii) as an index of fatigue processes occurring within a muscle. As an indicator of the initiation of muscle activity, the signal can provide the timing sequence of one or more muscles performing a specific task, such as during gait or in the maintenance of erect posture and also to provide information about the force contribution of individual muscles as well as groups of muscles [9]. The surface electrodes are located on surface of the skin to detect the motor unit action potentials from many muscle fibers.

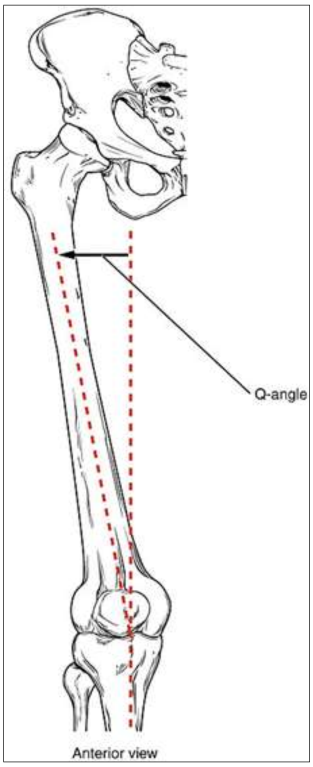

Fig 1: Q angle

Vertical jumping performance (VJP) reflects the explosive power in the lower extremities of an individual. It is performed to find the explosive strength of the athlete and the measure the lower body power. Vertical jumping capacity is important in many sports and is associated with the success in the related sport [10]. Vertical jump performance depends on the power of lower limbs and has been used as a standard tests of power performance and to estimate the composition of the muscular fibers [11, 12].

Objective of the Study

This study was conducted to measure the normal Q angle values among various male and female sportspersons and analyse the relation between Q angle and the muscle activation of Gastrocnemius and Tibialis Anterior muscles during vertical jump.

Materials and Methods

Participants

Thirty healthy 20-25-year-old adults enrolled at Mangalore University; India participated in this study [15 males: age 23.4 ± 1.5; height 1.72 ± 0.06 m; weight 68.4 ± 7.1 kg; Body Mass Index (BMI) 23.0 ± 2.8 kg/m^2; 15 females: age 24.1 ± 1.5 years; height 1.59 ± 0.06 m; weight 53.7 ± 10.6 kg; BMI 21.2 ± 3.7 kg/m2].

A convenient sampling method was used to recruit the subjects. The volunteers who agreed to participate in this study signed the Informed Consent Form and underwent an evaluation always performed by the same person. The subjects were regular sportspersons with more than three years of active sports participation at the inter-collegiate level. The Inclusion criteria were: (i) healthy by self-assessment with no history of Cardiac or pulmonary disease. (ii) No injury during the past 3 months prior to testing. Exclusion criteria were: (i) any condition which could affect joint or muscle function such as recent surgery, accident etc.or the measurement protocol. Permission was granted by the university for conducting the test.

Data Collection

The participants were familiarised with the testing procedures a week before the data collection, to minimise the learning effects and to increase reliability of the test. During the familiarisation the participants performed a maximal voluntary isometric contraction (MVIC) and a series of vertical jumps. During the actual tests, after a general warmup of about 10 minutes, the participants performed MVIC for the Gastrocnemius, Soleus and the Tibialis Anterior muscles. After about 5 minutes of recovery there were instructed to perform three repetitions of vertical jumps with a minute of rest between each repetition. The sEMG activity was acquired during each test trial. All measurements were conducted in the uniform conditions of temperature and humidity.

Maximal Voluntary Isometric Contraction

The subjects were acquainted with the testing procedures. General and specific warm up was done by performing several submaximal contractions of the ankle and hip flexors and extensors. After the warm-up, athletes completed three trials of ankle extension and flexion (plantar flexion and dorsi flexion) to record MVIC of both gastrocnemius and tibialis anterior muscles. One minute rest was given between each trial.

During the plantar flexion test for the gastrocnemius muscle, the participants seated in the leg extended position with the straps being fixed under the ball of the feet. Emphasis was placed on pulling the heel upward. For maximum resistance in this position, pressure was applied against the forefoot as well as against the calcaneus.

The Soleus muscle was tested with the subject seated on a bench with the knee bent 90 degrees and foot on the floor. Maximal resistance was placed on the thigh against which the subject had to try to perform plantar flexion trying to raise the heel upwards. Similar to the MVIC for Gastrocnemius, Emphasis was placed on pulling the heel upward and pressure was applied against the forefoot as well as against the calcaneus.

For the Tibialis Anterior muscle, the same test as for gastrocnemius was performed, but the strap was placed on the metatarsals and the subject had to try to perform dorsi flexion against the resistance.

MVIC was performed separately for the right and left leg muscles. For all MVIC attempts, the subjects were instructed and motivated to perform maximally. The subjects were verbally motivated during the maximal attempts. Each trial was performed for 4-5 s.

Measurement of Q angle

The Q angle is defined as the angle between a line connecting the center of the patella and the patellar tendon attachment site on the tibial tubercle and a second line connecting the center of the patella and the anterior superior iliac spine on the pelvis when the knee is fully extended [13].

The Q angle on the dominant side was measured with subjects standing barefoot [14]. All angles were measured using the same goniometer (stainless steel, half circle goniometer, with two arms-one stationary and lengthened and the other movable arm (see Figure 2). The participants remained barefoot and with minimal appropriate clothing (shorts or tights), so as the anatomical points could be easily located and palpated.

The following steps were performed in measurement in the standing position: 1. Anterior superior iliac spine (ASIS) was located and marked. 2. The outline of patella was drawn and the centre of patella (CP) was defined as point of intersection of maximum vertical and transverse diameters of patella. 3. Tibial tuberosity (TT) was identified as the point of maximum prominence and was indicated as the center of TT [15] 4. The center of goniometer was placed on the center of patella. The stationary arm of goniometer was aligned with ASIS and the movable arm was aligned with TT. The angle formed between above two lines was defined as the Q angle and was measured in degrees [16].

Fig 2: Goniometer used to measure Q angle

Vertical Jump

The participants were made to perform three vertical jumps. They were given 60s rest in between jumps. SeMG data was collected during these jumps.

Surface Electromyography

The sEMG data of muscle activity was collected using Trigno Avanti EMG sensors (Delsys Inc., Natick, MA, United States) and streamed to Labchart 8.0 software (Ad Instruments, USA), through which the data was processed and converted to quantitative data. The appropriate area of the legs was shaved and cleansed with alcohol prior to application of EMG sensors.

The sensors were placed on the selected muscles according to the ‘‘Surface electromyography for the Non-Invasive Assessment of Muscles (SENIAM)’’ recommendations (seniam.org).

Gastrocnemius Medialis and Lateralis: The sensor is placed on the most prominent bulge of the muscle on the medial as well as the lateral side.

Soleus: The sensor is placed at 2/3 of the line between the medial condyle of the femur and the medial malleolus.

Tibialis Anterior: The sensor is placed at 1/3 of the line between the tip of the fibula and the tip of the medial malleolus.

The sEMG signals from each electrode were amplified (input impedance 120 kΩ; signal to noise ratio 750. Surface electrodes were connected to a base station (Trigno Base Station, Trigno Wireless System, Delsys, Natick, MA, United States) and streamed continuously to a computer through an analog to digital converter (Lenovo thinkpad P14s). All data were filtered with a 10 Hz high-pass and a 500 Hz low-pass Butterworth filter.

Surface electromyography recording

The root mean square (RMS) was computed and used to assess sEMG recorded during jump testing [17]. During the Vertical Jump the EMG activity during the eccentric and concentric phases was recorded in its totality. The RMS of the sEMG data was expressed as a percentage of MVIC [18] using the highest sEMG recorded during MVIC trials [19]. The reliability of these measures has previously been established [20].

Statistical Analysis

The data was analysed using Excel and SPSS software wherever appropriate. Data are presented as mean±SD. The significance of difference between means and coefficient of correlation was tested at 0.05 level of significance.

Table 1: Demographic Characteristics of the participants

Gender	Age	Height (mts.)	Weight (Kgs)	BMI
Female	24.13±1.55	1.59±0.06	53.73±10.64	21.20±3.70
Male	23.53±1.55	1.72±0.06	68.40±7.14	23.03±2.84

Note: The data represents values represent the means of 15 subjects each and are expressed in RMS mV for eight muscles.

As mentioned earlier, there is not much difference in their age and body mass index which would serve to make the data more reliable, since the variable vertical jump is influenced by a large extent by the body weight.

Table 2: Q angle values between males and females

Subject Gender	Q angle	T ratio	P value
Female	14.87^0±3.39	6.20	0.00***
Male	8.47^0±2.10		

Note: ***Highly significant (P value < P 0.05).

There is a significant difference in Q angle between male and female athletes at 0.05 level of significance. It is an established that women tend to have a greater Q angle than men due to their skeletal structural differences [21]. This study confirms the earlier findings.

Table 3. Muscle activation RMS between males and females

Muscles	Male	Female
Left Medial Gastrocnemius (LMG)	0.229±0.081	0.163±0.063
Left Lateral Gastrocnemius (LLG)	0.207±0.073	0.138±0.043
Left Soleus (LS)	0.271±0.106	0.175±0.050
Left Tibialis Anterior (LTA)	0.199±0.078	0.208±0.087
Right Medial Gastrocnemius (RMG)	0.304±0.127	0.240±0.042
Right Lateral Gastrocnemius (RLG)	0.255±0.124	0.213±0.071
Right Soleus (RS)	0.243±0.07	0.206±0.063
Right Tibialis Anterior (RTA)	0.197±0.082	0.218±0.073

Note: The values represent the means of 15 subjects each and are expressed in RMS mV for eight muscles.

The Study indicates that muscle activation in the form of raw data converted to RMS is more in males except the tibialis anterior muscles. It can be assumed males are able to activate their muscles more due to the bigger mass and power of their vertical jump. These RMS data is converted to the percentage of MVIC which shows that the females use more percentage of activation of the selected muscles (see Table 3 and Figure 3). This could indicate that due to the inherent lesser muscular force, the women have to use a greater percentage of their MVIC to propel their body upward. Still, there is no significant difference in the percentage muscle activation except for three muscles i.e., left soleus, right and left tibialis anterior.

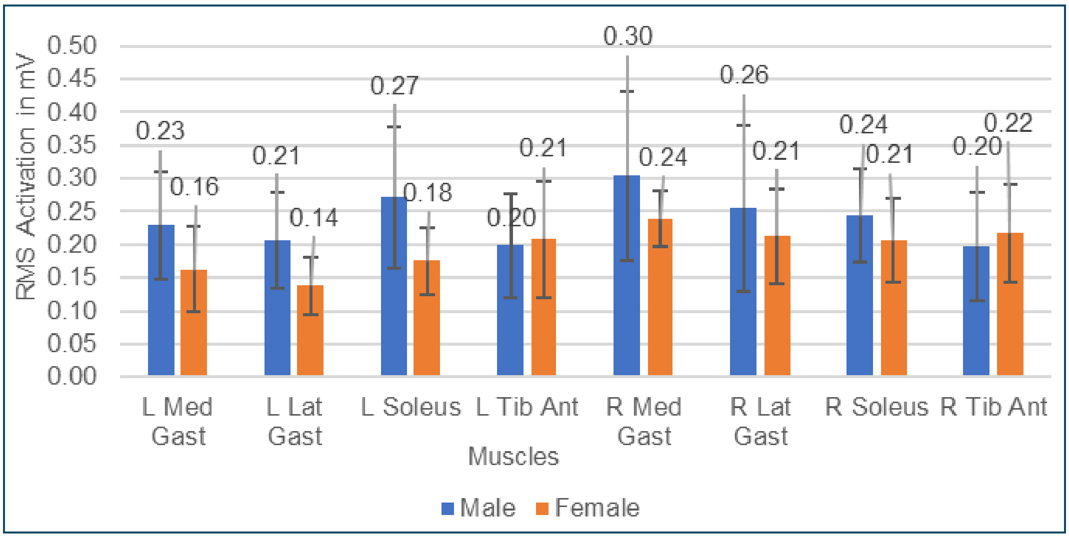

Fig 3: Muscle activation RMS between males and females

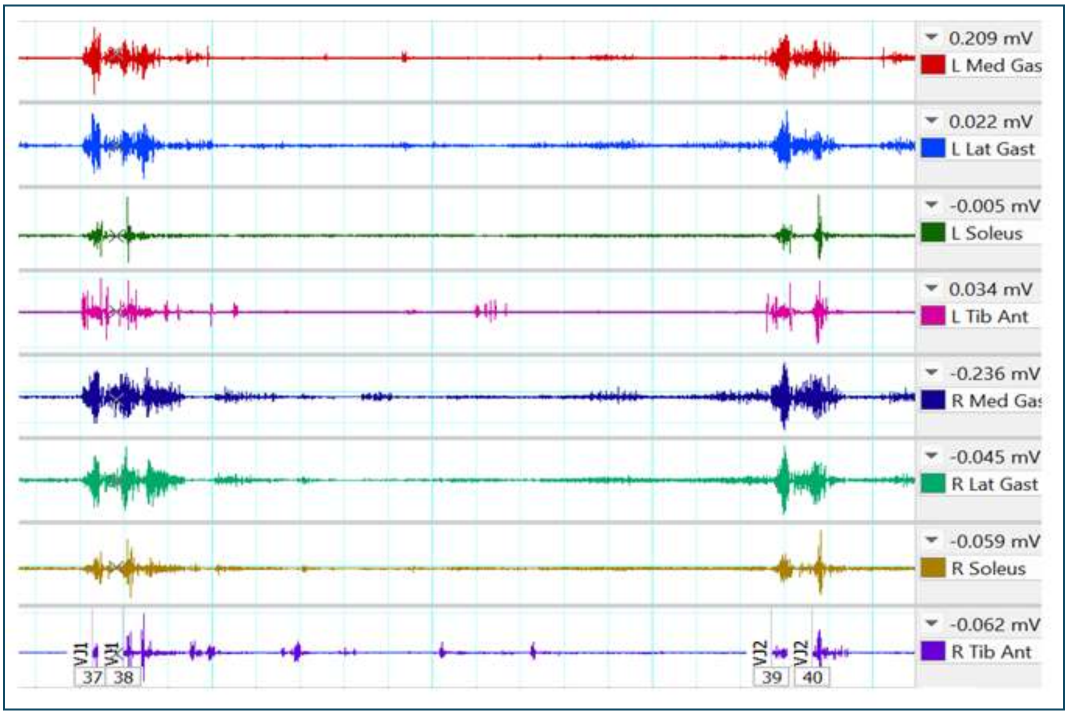

Fig 4: Raw data of muscle activation during vertical jump

Table 4. Percentage of Muscle activation between males and females

Muscles	Male	Female	p value
LMG	98.5±26.1	107.4±52	0.559
LLG	86.3±22.9	113.1±56.1	0.098
LS	123.7±54.3	177.8±49.8	0.018
LTA	64.3±42.1	119.3±79.9	0.025
RMG	101.9±34.4	105.9±25.6	0.717
RLG	87.6±31.4	117.9±53	0.067
RS	167.3±59.9	145.3±32.3	0.220
RTA	53.1±23.9	95.5±51.3	0.008

Note: The values represent the means of 15 subjects each and are expressed in % of muscle activation for eight muscles.

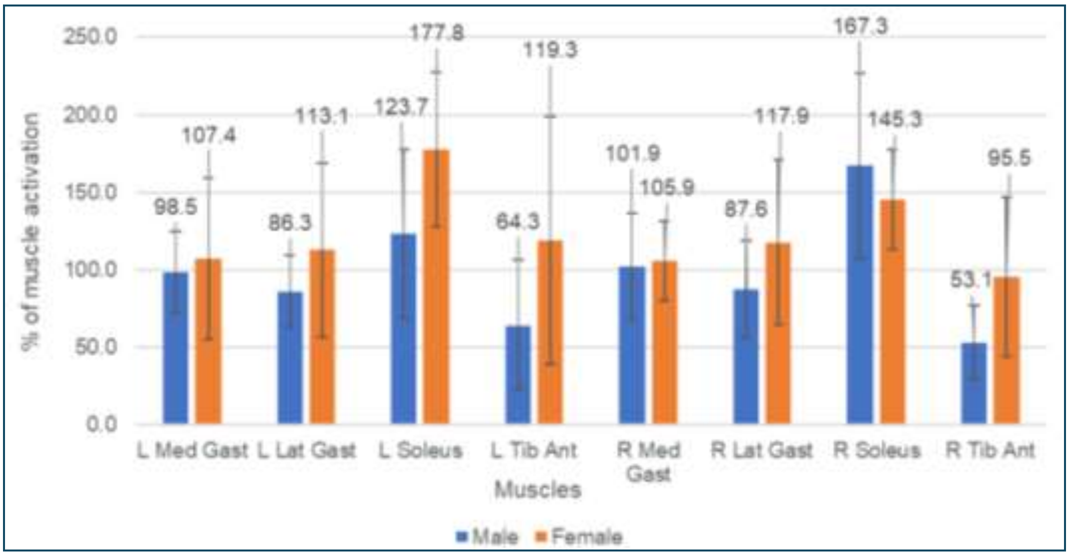

Fig 5: Percentage of muscle activation between males and females

Table 2 indicates that there is significant difference in Q angle between men and women, though there is no significant difference in muscle activation between them. This would indicate that Q angle does not exert a significant influence on the activation of the muscles in the lower leg during vertical jump performance.

Table 5: Correlation between Q angle and Muscle activation in males

Muscles	% muscle activation	Q angle	r
LMG	98.5±26.1	8.47±2.10	-0.29
LLG	86.3±22.9		-0.13
LS	131.3±51.8		0.62
LTA	64.3±42.1		0.16
RMG	101.9±34.4		-0.34
RLG	87.6±31.4		0.15
RS	167.3±59.9		-0.08
RTA	53.1±23.9		-0.01

The objective of this study was to find out if there was any relationship between Q angle and muscle activation of the muscle of the lower leg i.e. gastrocnemius, soleus and tibialis anterior. The results indicate that there is a good positive relation between Q angle and LS and a reasonable negative relation with LMG and RMG in men. The rest of the muscles show negligible relation with the Q angle which in not conclusive (see Table 5). In the women data, it can be seen there is fair negative correlation between Q angle and lateral gastrocnemius in both the legs. In LMG and RTA there is a negative correlation while the rest is nearly neutral (see Table 6). This could point out to the fact that a greater Q angle may have a negative tendency toward the way a muscle reacts during vertical jump.

Table 6: Correlation between Q angle and Muscle activation in females

Muscles	% muscle activation	Q angle	r
LMG	107.4±52	14.87±3.39	-0.25
LLG	113.1±56.1		-0.59
LS	177.8±49.8		0.08
LTA	119.3±80		-0.09
RMG	105.9±25.6		0.11
RLG	117.9±53		-0.47
RS	145.3±32.3		-0.06
RTA	95.5±51.3		-0.27

Discussion

The objective of the study was to analyse the effect of Q angle on the activation of lower leg muscles, namely, Gastrocnemius Medialis (GM), Gastrocnemius Lateralis (GL), Soleus (S) and Tibialis Anterior (TA). Studies have documented the influence of Q angle on the mechanics of the knee joint [22] and its indication to the pathological conditions of the patella-femoral joint [23, 24]. Since the Q angle is the median between the hip and the foot, this research was conducted to find the relationship between the lower leg muscles and the Q angle.

The subjects selected were sportspersons having similar physical characteristics, who were involved in active sports for at least five years and were free from any lower leg injuries or pathological conditions. It is an established fact that Q angles in females is greater than in males due to various anatomical differences, and this study reiterated that fact. The Q angle of the females was 14.87^0±3.39 and males was 8.47^0±2.10 which was highly significant at .05 level of significance.

The muscle activation of the selected muscles was acquired using the Delsys Avanti Trigno system sensors on both the legs i.e., right and left. The raw signals were streamed to Ad Instruments software Lab chart 8 and converted into RMS. This was further converted into percentage of the MVIC of each muscle. This Study indicates that muscle activation in RMS is more in the males in most of the muscles, except the anterior, which can be assumed to be the result of the negligible role of those muscles in the vertical jump. The percentage of activation of the selected muscles (see Table 3 and Figure 3) indicates that women use a greater percentage of their MVIC in the vertical jump. But there is no significant difference except for three muscles i.e., left soleus, right and left tibialis anterior (177.8±49.8 and 123.7±54.3, 119.3±79.9 to 64.3±42.1 and 95.5±51.3 to 53.1±23.9 respectively).

So, one can make a safe assumption that on the whole, there is no significant difference in contribution of the lower leg muscles to vertical jump in males and females. This would lead to the fact that Q angle would not exert a significant influence on the activation of the muscles in the lower leg during vertical jump performance.

The results of the study also indicates that there is a positive relation between Q angle and LS and a reasonable negative relation with LMG and RMG in males. The rest of the muscles show negligible relation with the Q angle leaning towards the negative (see Table 5). In the female data, there is fair negative correlation between Q angle and LLG, RLG. In LMG and RTA there is a negative correlation while the rest is almost neutral (see Table 6). On the whole, the relationship data though not conclusive, shows a negative inclination between Q angle and lower leg muscle activation during vertical jump.

Conclusion

In light of the above discussions, it can be concluded that there is no significant relationship between Q angle and muscle activation of the lower leg while performing vertical jump. The activation between males and females differs, though the significant values are present in only a few muscles which makes the decision on significance inconclusive. It should be remembered that various other factors affect the vertical jumping performance such as leg strength, body weight, training, sport involved etc. which could have an influence on the muscle stimulation. Therefore, further investigation is needed to isolate these factors for the purposive determination of the effect of Q angle on selected muscle activation.

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